The Assessment of Macroinvertebrates in the Balcones Canyonlands Preserve

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Abstract

Water systems are an essential aspect of human development. As such, the assessment of how pollution, whether natural or anthropogenic, affects quality is pertinent to successfully managing aquatic systems. Many of the current methods available are expensive and time consuming and not realistic to implement. A rapid bioassessment, the use of invertebrate species to measure the quality of the water, is an inexpensive and efficient way to identify possible ecosystems that may be at risk. Macroinvertebrate data from the Wild Basin Wilderness Preserve and its associated Bee Creek watershed is limited compared to other streams monitored in the Austin area. The main objective of this project was to establish protocols for the collection of invertebrates in Bee Creek. The protocols were focused on facilitating future studies to implement a rapid bioassessment at Wild Basin. Two other streams, Bull Creek and Barton Creek, were also sampled providing comparative data to that collected at Wild Basin. Data obtained from the Austin Watershed Protection Department were used to observe the historical trends in the streams sampled. Data were then compared with temperature and rainfall during the collection periods. Trends in the historical data indicated that the streams were consistently being affected by anthropogenic influences but there was no significant chronological change. An inverse correlation with temperature and stream health rating was identified.

Significance of Water Quality Assessment

The natural environment can be sensitive to changes that are caused naturally or by human activity. It is important to monitor any changes to the natural environment that are a result of rapidly developing urban areas. Pollution from anthropogenic sources and from changes in hydrological conditions, like climate change and erosion, can become serious problems for environmental management (Damo & Icka, 2013). Monitoring water quality can help identify perturbations and allow for proper mitigation of these effects.

Comparison of overall ecosystem health is possible by studying water quality, which assists in the ability to identify ecosystems affected by human development, natural disturbances, or those which are relatively untouched (Damo & Icka, 2013). The assessment of water quality can be expensive to implement and the reliability of the data may be difficult to ascertain (Mannina, 2011). In order to maximize the reliability of the data, water quality assessments need to focus on monitoring systems over multiple seasons.

Emphasis on conservation is placed on the need to effectively preserve the proper flow of water through ecosystems and repair the damage done as a result of human interaction. Little emphasis however is placed on how the local biology is affected. Using the food web to assist in the monitoring of water quality has proven to be an effective method for understanding and controlling the impacts of human development on the ecosystem (Chen et al., 2013; Scharf, 2008).

Rapid Bioassessments are cost effective surveys used to quickly analyze water quality (Barbour, 1999). The use of invertebrate assemblages allows for the compilation of data that is easy to interpret, making it ideal for presentations to the public. Macroinvertebrate assessments are also non-invasive and have little long-term effect on the environment.

The use of invertebrate assessment is universally accepted as a means to accurately monitor the health of water systems (Boonsoong, et al. 2009; Hartmann, Moog, & Stubauer, 2010). Invertebrates are the ideal selection for bioassessment surveys since they demonstrate the widest variety in form and function. Their taxonomic variability results in invertebrates having the highest number of niche differentiations, which allows for invertebrate compositions to be strong indicators of overall health.

A reference stream is an important component and requirement of macroinvertebrate assessments (Awal & Svozil, 2010; Schopmeyer, Vroom, & Kenyon, 2011). In order to determine if a water system has been affected by pollution, historical data should be available to describe the pre-existing invertebrate compositions. This can help to identify changes in water quality and help the overall monitoring of the ecosystem.

One of the more integral features in the design of rapid bioassessment protocols is they allow for comparisons between nearby water systems (Schopmeyer et al., 2011). Regular macroinvertebrate surveys have not been implemented within the Wild Basin Wilderness Preserve and data regarding invertebrate assemblages present in Bee Creek, the stream associated with the preserve, are limited. As a result, there are no comparable historical data available.

Macroinvertebrate surveys are an effective way to perform an initial assessment of the overall quality of the water system (Hartman et al., 2010). Invertebrates make up 96% of known animal species and are essential to the ecosystem established in freshwater environments. Their presence fulfills an essential ecosystem role in breaking down nutrients required for the healthy functioning of ecosystems (Voshell, 2002). Freshwater invertebrates are able to give a strong indication of water quality and are used in freshwater quality assessments more than any other freshwater organism (Lear et al., 2009). Polluted or disturbed areas can be identified by relating the taxonomic composition with sensitivity or tolerance to sites that are relatively pristine (Hilsenhoff, 1988). Temporal studies on a large scale can be helpful and allow for accurate assessments of how both historical and present conditions influence the observed distribution (Hoang el al., 2001).

Benthic macroinvertebrates are advantageous because they are widespread, diverse, have limited mobility, a long generation time, and are easy to sample (Resh, 2008). Macroinvertebrate compositions can reliably indicate short bursts of pollution, for example runoff as a result of heavy rain, and also indicate long-term exposure to persistent venues of pollution (Hoang et al., 2001). This is essential to functionality of invertebrate assays in determining pollutants that are present in the ecosystem.

The study focused on establishing a protocol for assessing the aquatic macroinvertebrate fauna within Wild Basin, allowing for the testing of these certain sites in future studies. It also provided a baseline to allow for Wild Basin to be integrated into current protocols used by local agencies. Finally, the study focused on assessing long term trends in the Austin area.

Methods

Site Description

The study focused on three locations within Austin, which are owned and monitored by different agencies working under the Balcones Canyon Preserve Land Management Plan (Figure 10). Wild Basin was compared to streams that are managed by independent organizations and have long-term historical data. Bull Creek, run by the city of Austin, is frequently assessed. The

Nature Conservancy manages the sites for Barton Creek where collection for the study occurred. Wild Basin is owned by Travis County, and is managed by St. Edward's University.

Bull Creek

Sites within Bull Creek were selected based on their association with public parks. This decision was made to avoid permitting issues, as the creek winds through the city of Austin and would involve multiple agencies. Sites varied in water flow and proximity to urban development. Differences were noted and rated using a habitat assessment form.

Barton Creek

Most of the water in the Barton Creek system is from surface runoff (Balcones canyon land management plan, 2007). The preserve is surrounded by urban development making it a potentially sensitive location. A permit was required to collect in Barton Creek Habitat Preserve; the permit had not yet been approved during the winter sampling period so data from this area was only collected during the spring sampling period.

Bee Creek

Wild Basin is a much smaller location than Barton Creek and Bull Creek and is potentially more impacted by urban development than the other two sites. There is limited information regarding the water quality within the Wild Basin Wilderness Preserve (Balcones canyon land management plan, 2007). The preserve is located near a busy highway, is close to a developing urban area and is surrounded by constant human activity. This leads to a situation that may result in pollutants rapidly entering Bee Creek inside the Wild Basin Wilderness Preserve. A permit was required to collect in Wild Basin Wilderness Preserve; the permit had not yet been approved during the winter sampling period therefore sampling in winter occurred in areas surrounding Wild Basin. This included three local residents who provided access to their property. These three sites were located downstream of Wild Basin. Two additional sites located upstream of Wild Basin were selected, these sites were situated right outside the jurisdiction of the preserve.

Sampling Method

In order to account for seasonality in the composition of invertebrates present there were two time periods of collection, one starting in mid-December and the other in late February. It was determined that two sampling periods would increase the reliability of the data collected (Collier, 2008; Mackey, Cooling, & Berrie, 1984). Sixty-one to ninety-two percent of all species present are collected within two sample sites (Mackey et al., 1984).

Five sites were selected during the winter sampling. The GPS coordinates of each site was recorded. Four sites were selected at Barton Creek and inside Wild Basin for the spring sampling; this was due to the inability to select a fifth site. Records of the environmental factors present at the sites were recorded using a habitat assessment form. This document consisted of a description of vegetation present in the water, description of the leaf coverage and the water dynamics that could potentially affect distribution of invertebrates.

The method used for sampling can greatly affect the results (Pinna, Marini, Mancinelli, & Basset, 2014). Sampling protocols and collection methods were similar to those used by the Austin Watershed Protection Department. Sampling at each site was conducted using two collection methods. The first was the use of kick nets to collect a qualitative assessment of individuals and the second method utilized Surber samplers to provide a quantitative assessment of tolerant and intolerant families present. The study used one Surber sampler for each site where collection occurred. Surber samplers were used in order to provide data that were processed using the Hilsenhoff Biotic Index (HBI) (Hilsenhoff, 1988). The Surber sampler was used at a target riffle site for the span of one minute. This time period allowed for a representation of what individuals are present in the given area. Surber samplers were not used in areas where riffles do not occur, or where the water column was too deep.

Kick nets were used at all sites except for Canyon Creek Park. These types of nets are reliable forms of collection and do not require expensive equipment to operate (Mackey et al., 1984). Samples collected with these methods are more consistent than other methods available. Pond net and kick net samples are extremely sensitive to operator bias (Mackey et al., 1984). In order to maintain consistency in the data, each individual repeated their collection method at each site. Using different operators would have resulted in a decrease in the reliability of the data. Nets were selected as the method of collection over less invasive techniques because samples collected with nets are more reliable (Jocque, Kernahan, Nobes, Willians, & Field, 2010). Due to inexperience with the sampling methods it was determined that this would affect the quantitative results for the winter sampling. As result, winter samples were only assessed using qualitative methods.

Samples collected were placed in separate vials, containing eighty percent ethanol, and were labeled with the date, site and method of collection. Samples collected using the surber net were placed in vials separate from the samples collected using the kick net.

Identification and Calculation of Biodiversity Indices in Collection

Invertebrates were identified to the family level with the use of a dissecting microscope. Snails (Gastropoda) were not included in the analysis due to the inability to identify their family level.

Identification and Calculation of Biodiversity Indices in Collection in Historical Data

Austin Watershed Protection Department provided historical data associated with the streams assessed in this study. The data spanned eighteen years of collections and were a compilation of various studies conducted on the streams.

Analysis

A macro was designed in Microsoft Excel to key the Hilsenhoff Biotic Index Rating (HBI) with the appropriate families (Hilsenhoff, 1988). The historical data set had five different types of collection methods that were used: dip net, composite Surber, single Surber, minisurber and subsampled single Surber. It was determined that minisurber and subsampled single Surber data were not comparable to one another and the data associated with these methods were discarded. The composite Surber data were described as being a combination of three separate Surber samples combined at each stream site. Data from these sites were divided by three in order to normalize the data and make it comparable to the single Surber data. Some sites in the historical data set also had multiple single Surber samples denoted. Each site was then analyzed with the use of the HBI to identify its health rating.

In order to discover any significant associations with climate the historical data were assessed to determine if there were correlations with temperature or precipitation. Data were obtained from NOAA datasheets from the Austin Camp Mabry station for the years 1996 to 1999 (“Climate Data Online: Dataset Discovery”, n.d.). All other data were gathered through Weather Underground, including for samples collected during the study (“Weather History for Austin, Tx”, n.d.). For all collections, a month was selected to obtain the appropriate data. If collections occurred before the 17th of a particular month, data from the previous month was used. If a multiple-day collection series took place before and after the 17th, the month was selected based on when the majority of collections took place. For yearly data, collections before August were assigned the previous year. These methods were used to minimize error. Any multiple-day collections were assigned the same month or year in the caution of data reliability.

Trends and statistical significance of each variable was assessed through the use of SPSS. Data were analyzed to determine if there were statistical correlations between HBI rating and climate values. Dimension reduction was used to combine data (like maximum, mean and minimum temperature) to determine if the trend was associated with a specific value or temperature itself. When significant trends were identified ANOVA and ANCOVA tests were run to determine the significance of the effect.

Results

Winter samples were assumed to only be relevant as a qualitative assessment of the macroinvertebrates present in the stream system.

Collection Results (Diversity)

Winter samples at Bull Creek had an average total richness of 14 with the highest rating being 20, at St. Edward’s Park site, and the lowest being 8, at Great Hills site (Table 1 in the Appendix & Figure 1). The most dominant group observed was Ephemeroptera. Spring samples at Bull Creek had an average diversity of 10 with the highest rating being 15, at Tributary 4 site, and the lowest being 6, at the Great Hills site. The most abundant family observed during the spring was Trichoptera.

The winter samples associated with Bee Creek and outside Wild Basin had an average diversity of 8 with the highest rating being 14, resident site one, and the lowest 0, the trash site. The most abundant groups collected were Trichoptera and Ephemeroptera. Spring sites associated with Bee Creek and outside Wild Basin had an average diversity of 7 with the highest rating being 10, at the resident site one, and a lowest rating of 2, the Trash site. The most common groups during the spring were Odonata, Diptera, Trichoptera and Ephemeropta.

Spring Sites associated with Bee Creek and Inside Wild Basin had an average diversity of 10, with the highest rating of 13, site 1 and the lowest being 6, site 3. The most dominant group was Trichoptera.

Spring sites at Barton Creek had an average diversity level of diversity of 13, with the highest amount of variation being 19, site 1 and the lowest being 7, site 4. The most abundant family collected was Ephemeroptera.

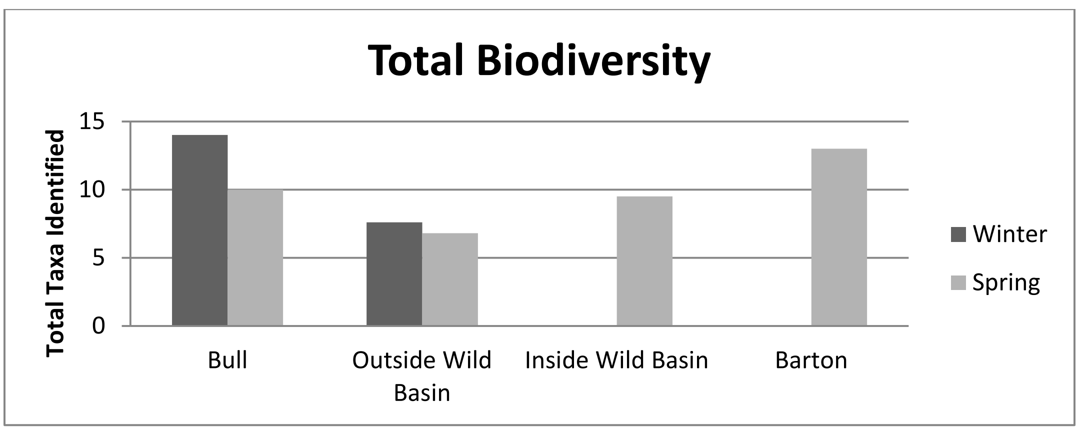

Figure 1: Total biodiversity observed during sampling at each water system.

Sites were assessed for quality of habitat. Winter samples at Bull Creek had an average quality rating of 138.9 (Figure 2). The average rating during the spring collection was 130.8. Collections that occurred outside Wild Basin during the winter period had an average rating of 107.2; the spring samples had a rating of 98.7. Samples inside Wild Basin during the spring had an average habitat rating of 143.75. Spring samples that occurred at Barton Creek had an average habitat rating of 133.5.

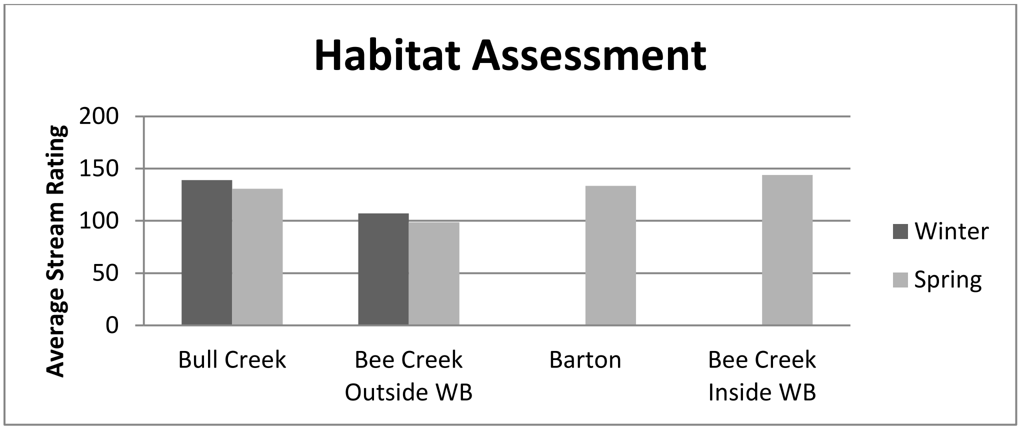

Figure 2: Assessment of habitats based on rating. Higher rating indicates high quality sites.

Collection Results (Qualitative)

Samples were qualitatively assessed using the composition of macroinvertebrate groups present and their ability to tolerate pollution present in the environment (Table 1 in the Appendix) (Macroinvertebrate Survey). Winter samples at Bull Creek had an average rating of 61 with the highest rating being 93, St. Edward's Park site, and the lowest rating being 28, Great Hills site (Figure 3). Spring samples at Bull Creek had an average rating of 50 with the highest rating being 62, St. Edward's Park site, and the lowest being 31, Great Hills site. Winter samples associated with Bee Creek and outside Wild Basin had an average rating of 39 with the highest rating being 73, resident site one, and the lowest rating being 0, Trash site. Spring samples associated with Bee Creek and outside Wild Basin had an average health rating of 29 with the highest rating being 42, resident site one, and the lowest rating being 10, Trash site. Spring samples associated with Bee Creek and inside Wild Basin had an average rating of 47 with the highest rating being 65, site 1, and the lowest being 35, site 2. Spring samples at Barton Creek had an average rating of 89 with the highest rating being 113, site 1, and the lowest rating being 42, site 4.

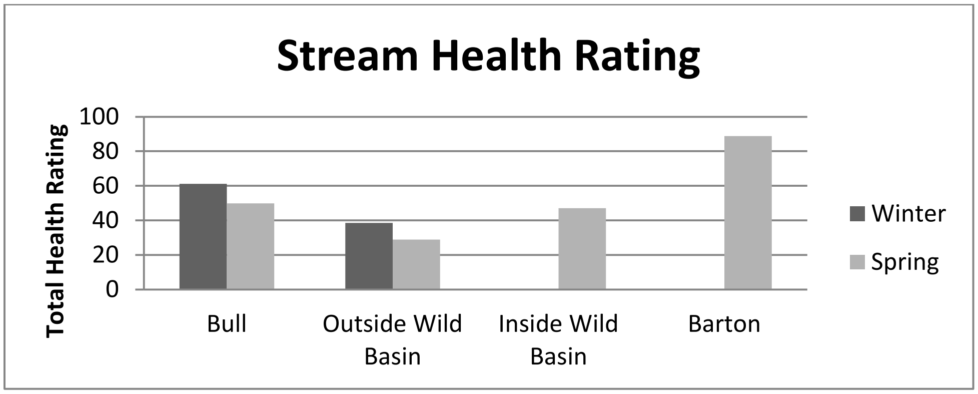

Figure 3: Health rating assessed using macroinvertebrate survey technique. Higher rating indicates higher quality.

Collection Results (Quantitative)

Surber samplers were not possible at all sites sampled. Sites where surber samplers were used were assessed using the Hilsenhoff Biotic Index (HBI) (Hilsenhoff, 1988). Winter samples were not assessed using the HBI due to inexperience using the sampling method; only spring samples were assessed with this method (Table 2). Bull Creek had an average rating of 4.84 with the highest rating being 6.27, Great Hills site, and the lowest being 4.03, Bull Creek Park site (Figure 4). Sites associated with Bee Creek and outside Wild Basin had an average rating of 8.2 with the highest rating being 10, Trash site, and the lowest rating being 6.42, resident site 3 (Table 2). Sites associated with Bee Creek and inside Wild Basin had an average rating of 4.63 with the highest rating being 5.25, site 4, and the lowest rating being 3.86, site 3. Barton Creek had an average rating of 4.96 and the highest rating was 5.33, site 3, and the lowest was 4.74, site

1. The most abundant group sampled during the period of this study was the family *Baetidae* (Figure 5).

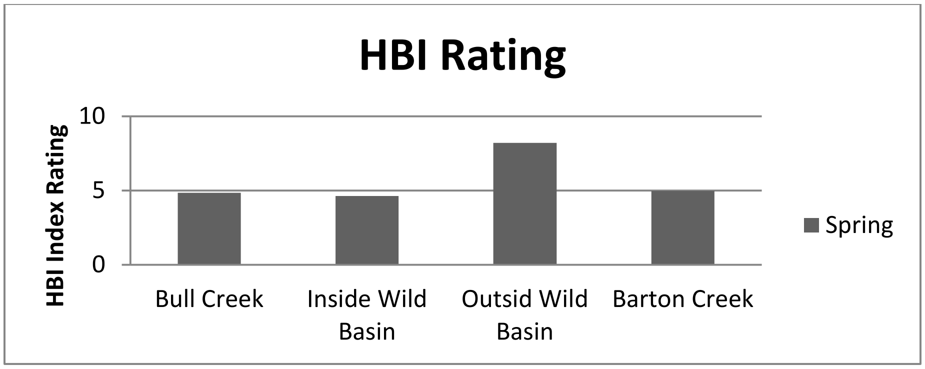

Figure 4: HBI index rating assessed at sites where Surber sampler was used. Lower rating is indicative of higher water quality.

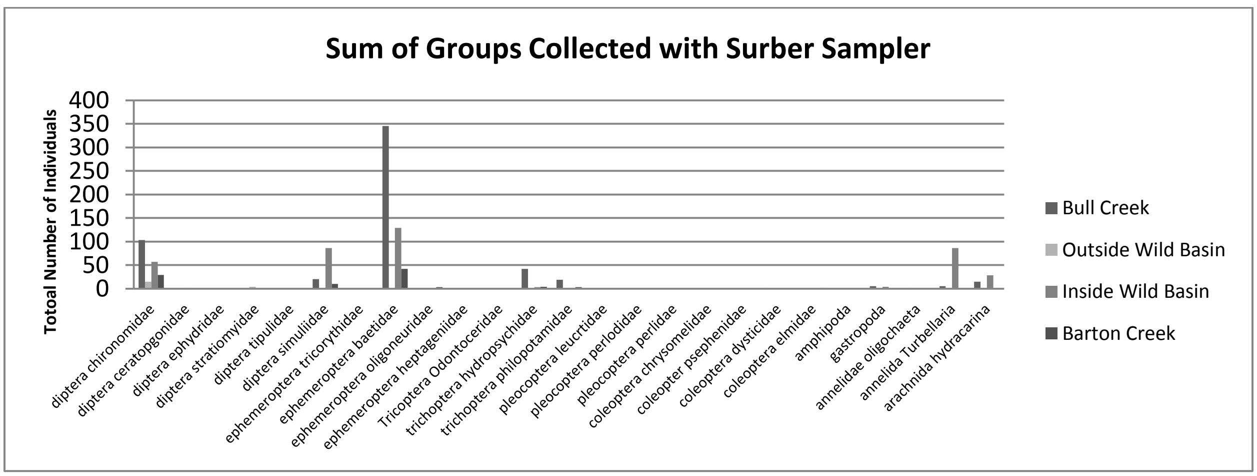

Figure 5: Total number of each family that was collected during the course of this study.

Historical Data

Historical data was analyzed using the SPSS program to determine significant correlations. All three streams were assessed for average HBI rating per year (Figure 6). There was no significance in the changes in rating over time. There was also no statistical significance determined as a result of precipitation. Based upon the historical data there was no statistical significance found with temperature or precipitation with Bee Creek. The sample size for Bee

Creek was n=15, which is too small to determine any significance. Temperature was determined to have a statistical correlation with rating at Bull and Barton Creeks. The adjusted R squared value for temperature and Bull Creek was -.244 and a P value < .01 (Figure 7). The adjusted R squared value for temperature and Barton Creek was -.150 and a P value < .01 (Figure 8).

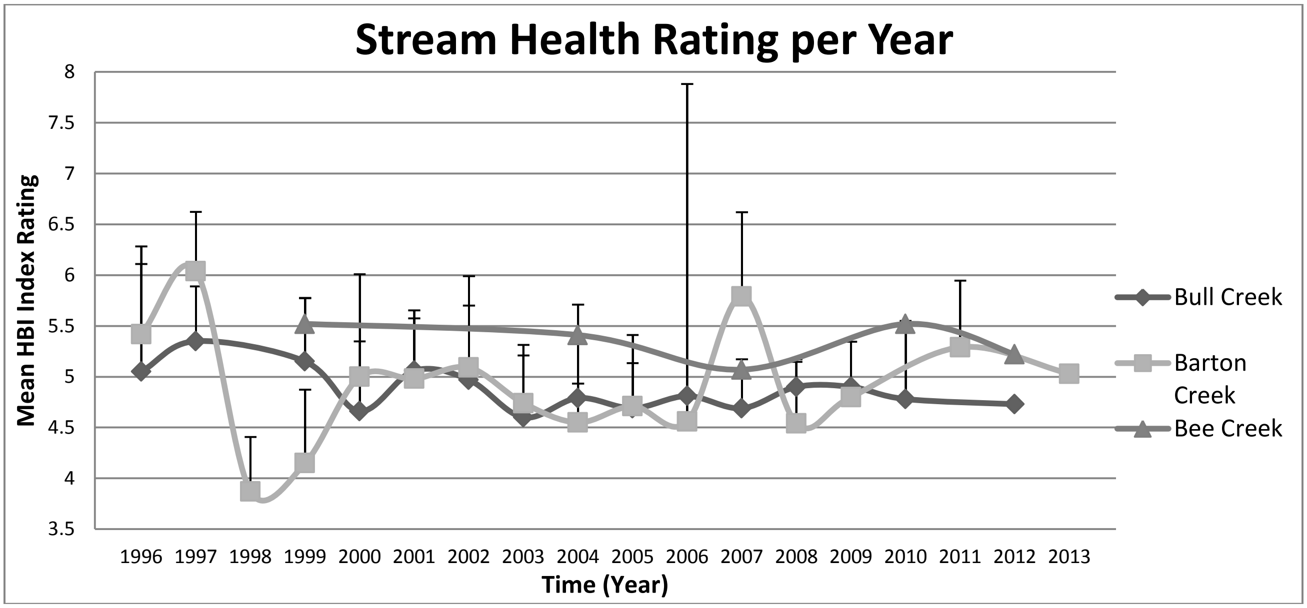

Figure 6: Average HBI rating for creeks per year.

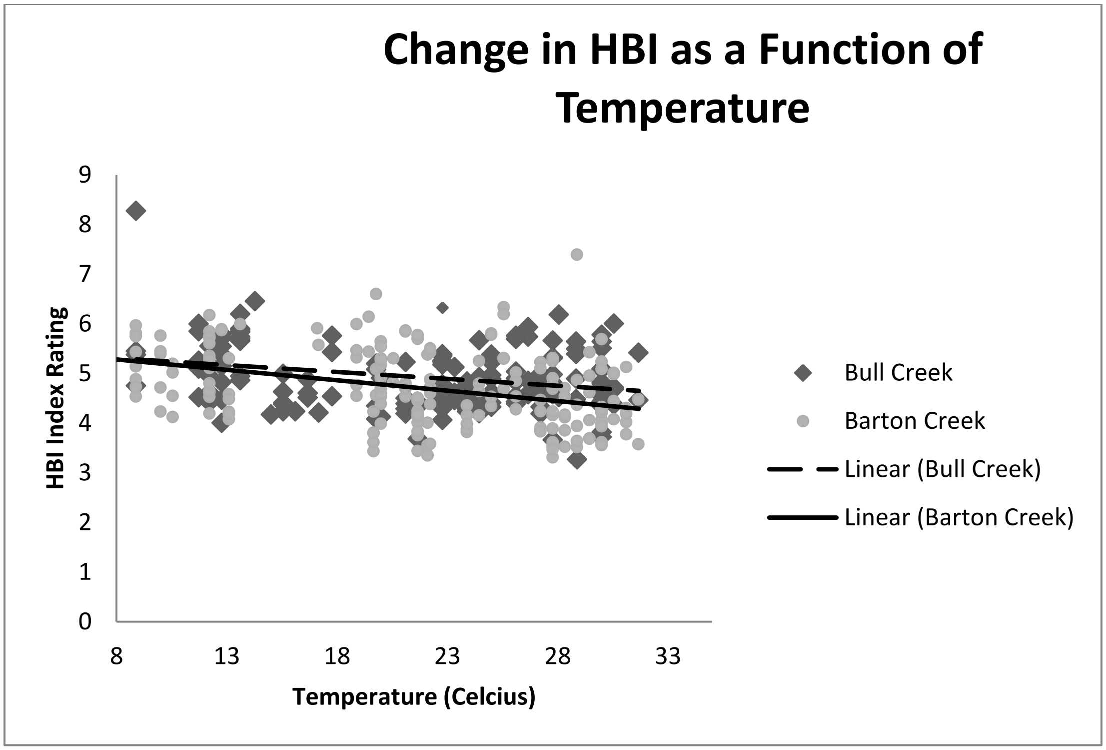

Figure 7: HBI rating at Bull Creek correlated with air temperature.

Discussion

Biodiversity in Collections

As there was no significant variations across habitat assessments at Bull Creek, Barton Creek and Bee Creek inside Wild Basin, they were identified as being comparable in health of ecosystem and ability to support macroinvertebrate assemblages. The level of biodiversity seems to suggest that sites inside Wild Basin and at Bull Creek had similar amounts of variation. Barton Creek's level of biodiversity was the highest out of the three streams during the spring samples, which suggests that Barton Creek may have the highest level of environmental stability. This can also be explained natural variations in the stream sites. The habitat assessment between seasons at Bull Creek indicated that the habitats sampled were relatively equivalent yet the biodiversity varied. This may be the result of an environmental condition, which was not identified, affecting the variation in the creek. The sampling method was adjusted between these two collections, it also possible that this variation could be explained as a change in sampling protocol.

The samples seemed to show a trend of decreasing overall biodiversity between the winter and spring collections. This trend was more prominent in the Bull Creek sample sites than at the Bee Creek sample sites. During the spring sampling periods it was observed that there was a noticeable increase in the amount of algal growth when compared to the winter samples, which may be a result of urban runoff causing an eutrophication event. Eutrophication is indicative of excess nitrogen and phosphorus in the system and has been linked to reduction in biotic variation (Scheihing et al., 2010; Wang et al., 2012). Algal trends were not observed at Bee Creek inside Wild Basin or at Barton Creek inside the Barton Creek Habitat Preserve. Samples at Barton Creek had the highest levels of biotic variation and also had the greatest distance away from urbanization. The difference in variation may be attributed to the size of the riparian zone. Urban development within one hundred meters of stream sites has been shown to affect the biodiversity present (Lammert & Allan, 1999). Future studies should assess the presence of a correlation between levels of biodiversity and land use surrounding stream sites.

Qualitative Results in Collection

The trend for all the streams regarding stream health using the invertebrate survey technique is consistent with the trends observed in the variation of biodiversity. The two notable differences using this technique are that Barton Creek appears to have an overall healthier system and the variation between seasonality at Bull Creek was not as pronounced. This observation may be an indication that the sites where collection occurred at Barton Creek are more suited towards the collection of sensitive species. One of the effects of urbanization is that sedimentation increases in streams (Allan, 2004). This may result in Bull and Bee Creek preventing sensitive species observed in Barton Creek from successfully recruiting. In addition, there is strong evidence that changes in land use patterns have a pronounced change on community compositions (Li et al., 2012). Habitats that are more associated with wilderness regions have a tendency to have healthier macroinvertebrate assemblages compared to regions that are affected by urban development. It is however interesting to note that the specific sites sampled have a tendency to be more strongly correlated with the specific groups of macroinvertebrates. This suggests that the results observed might be a function of the site selection.

Quantitative Results in Collection

The assessment using the HBI rating is not conclusive in the assessment of overall health in the Bee Creek samples due to the fact that there is no long-term data set with which to compare the results to. As a result, only trends and qualitative observations can be identified. The samples collected at Barton Creek and Bull Creek are relevant due to the long-term data set available. The site labeled “Trash” lacks significance due to the small sample size collected.

The HBI rating at Bull Creek, Barton Creek and inside Wild Basin are similar and hovering around a rating of 4.5 to 5.0. This rating suggests that there is some level of pollution present at all three of these locations. This result also contradicts the results from the qualitative assessment, which states that Barton Creek is healthier than Bee Creek and Barton Creek. The observation suggests that all three streams are being affected by anthropogenic inputs to some degree. These ratings suggest that human input of chemicals may be affecting the health of the ecosystem present (Wang et al., 2007). During the time period where sampling occurred it was noted that there was a significant increase in algal growth in sites outside Wild Basin compared to sites inside Wild Basin. It was also noted that the sites outside Wild Basin were downstream of the sites of collection inside of Wild Basin. The results of the assessment also depict a situation where the collections outside Wild Basin had a higher HBI rating than sites inside. It is possible that the algal growth and the level of impact on the ecosystem are correlated (Scheihing et al., 2010). Anthropogenic influences are known to increase nitrogen and phosphorus and may lead to eutrophication events (Roy et al., 2003; Wang et al., 2012). It is possible the observed algal growth is a function of inputs into the stream as a result of human activity.

Historical Data Results

There was not a large enough data set to determine statistical significance at Bee Creek. The assessment of the historical data yielded little significant correlation over time at Bull Creek and Barton Creek. There are time periods where the rating fluctuates, for example years 1997-1998 and 2007, but the stream returns to hover around a rating of 5.0. This suggests that the creeks are in an environmentally stable state regardless of anthropogenic inputs. The result of the assessment does however indicate that the water systems are being moderately impacted by anthropogenic inputs. This is to be expected of habitats that are located in a major city that is rapidly developing. Despite the lack of any significant trend this does not mean that continued development will yield similar results. It is entirely possible that as the city continues to develop the creeks will be pushed beyond their tipping point of a balanced ecosystem and collapse.

It is important to identify the sources of the pollution in these sites in order to prevent the systems from destabilizing. Understanding how water systems are being affected by pollution after a restoration has occurred is essential in interpreting how to proceed with future projects. Assessments of the effectiveness of restoration project are rarely conducted (Selvakumar et al., 2010). Identifying how sites have improved is important in detecting where the project was inadequate and can be adjusted. Constant monitoring of long-term effects of restoration can lead to a better understanding of their overall impact (Collins et al., 2013). As a result, future studies may want to identify outlier sites that significantly vary from the average trend across the streams. This will allow for the identification of possible sources of pollution into the stream. In addition, it will allow for the selection of sites that are not being strongly influenced by anthropogenic development. Targeting these sites may allow conservation efforts to determine why these sites are not being influenced and attempt to implement these features to sites that are at risk.

Analysis indicated that temperature was significantly and inversely correlated with overall HBI index rating. This relationship states that as temperature goes up HBI index rating goes down, or that pollution levels drop. The correlation was -0.244 for Bull Creek and -0.150 for Barton Creek. The difference between creeks may be attributed to the overall variations in depth. Barton Creek is deeper than Bull Creek, which may result in the stream taking longer for temperature to adjust to the ambient temperature. The relationship is not very strong, indicating that it does not have a large effect on HBI rating. It is however worthy to note and future studies need to address the relationship in order to control for it.

The interaction between macroinvertebrates and temperature is a fairly unique concept and not much is conclusively known. Assessments of invertebrate assemblages have shown that overall non-sensitive species tend to thrive in warmer temperature compared to sensitive species (Dallas & Rivers-Moore, 2012). It is however extremely variable with some sensitive species being more tolerant at warmer temperatures than non-sensitive species. It is possible that the observation in study is due to the fact that the sensitive species present are more resistant to temperature changes than the non-sensitive species.

There is also evidence that macroinvertebrate compositions shift towards non-sensitive groups being more dominant in cold climates (Grab, 2014). This observation was observed as a result in seasonal and altitudinal changes. One possible explanation for the occurrence of this trend is that aquatic plants are more abundant in colder climates, which provides substrate for non-sensitive species to recruit (Brucet et al., 2012). Although, it may be an unlikely explanation for the trend in the Austin area, as sites of collection do not significantly vary in vegetation, with large rocks being the dominant feature for non-sensitive species to recruit. Temperature relationships like this, however, should be explored in order to assess their impact on the reliability of the results.

Interactions between the groups used in the HBI index assessment may be uniquely affected by temperature. One of the prominent effects of warmer temperatures is that oxygen availability decreases in the water column (Rotvit & Jacobsen, 2013). This can affect overall life cycles and quality of individuals that recruit (Forster et al.,, 2012). Oxygen availability can have profound effects on overall invertebrate diversity in the system (Jacobsen & Brandl, 2007). Non-sensitive species tend to be oxygen regulators and sensitive species are oxygen conformers. However, certain stoneflies, a sensitive family group, are able to exhibit regulatory capacities despite being oxygen conformers (Rotvit & Jacobsen, 2013). This observation is particularly interesting because it suggests that the trend may not be a simple interaction with temperature changes in the ecosystem.

Temperature can affect the lifecycles of the groups assessed using the HBI index and variation may lead to delayed lifecycles (López-Rodríguez et al., 2008). This may lead to observations in the trend associated with temperature being a delayed reaction to disturbances that occurred prior to collection. The climate in Austin during the collections conducted in this study was highly variable, with variation in temperature from near freezing to 21.1. It is possible that this inconsistent temperature variation may cause bias in the observation of the trend. In addition, there is evidence that warmer climates lead to mayflies, another sensitive species, to increase life cycles and incubation periods (Gilbert et al., 2008). This observation indicated that mayfly assemblages are highly dependent on temperature in the ecosystem. During the course of collection in this study it was observed that *Baetidae*, a Mayfly family, was the most prominent group collected. This may explain the trend as this group is extremely prevalent.

The historical assessment of HBI rating at Bee Creek yielded inconsistent results that reveal no significant trends. This is largely due to the small sample size. Despite the lack of information on the stream there appears to be a qualitative trend where the rating is slightly higher at the creek. The Wild Basin Wildlife Preserve is located near a major highway and in an area of rapid urban development and the limited data available at this site may make future important conservation efforts difficult due to lack of historical data with which to compare the current state to. In addition, there are unique features that make Wild Basin an interesting location to perform a macroinvertebrate assessment. Changes in river flow can affect the overall macroinvertebrate assemblage present (Dunbar et al., 2010; Shafroth et al., 2010). Bee Creek does not have consistent water flow throughout the year. This leads to a loss of stream connectivity, which can lead to clusters of isolated biology (Gilbert et al., 2008). Evidence suggests that sensitive species are able to tolerate these conditions but have difficulty recruiting once these conditions subside. As a result, once the stream reconnects non-sensitive species are observed to be more prominent. In addition, taxonomic variability is higher in intermittent streams, providing a unique perspective on biota present (Bêche et al., 2006). This trend may be useful in future assessment of Bee Creek and may explain the higher HBI rating observed so far. In addition to this, a large portion of the water in Bee Creek comes from ground water. Ground water has a tendency to be cooler than other sources of water and is independent of air temperature (Domisch et al., 2011). Sampling at Wild Basin may not show the temperature trend observed at Bull and Barton Creek and could prove useful in identifying the cause of the trend.

Conclusion

The use of macroinvertebrate assessments is useful in identifying changes in the ecosystem as a result of anthropogenic influences. Collections and assessments of this nature are beneficial in quickly scanning sites for potential risks to the environmental integrity. This study was used to identify overall trends of the creeks assessed. There are limitations to family level assessments of this nature. This first important issue is that family level assessments broadly characterize genus and species as equal in their ability to tolerate pollution in the environment (King & Richardson, 2002). Future studies should endeavor to characterize the stream compositions in a more detailed manner. This will allow for a stronger identification of overall trends in the water systems. Assessing macroinvertebrate compositions to the genus and species level will also allow for more accurate identification of variations between time periods and provide a clearer assessment of issues with water quality (Lenat & Resh, 2001). As a result, the trends observed may be more confidently assessed and interpreted.

The HBI index is a useful tool in comparing the overall health of the ecosystem. Future studies may want to use this assessment in conjunction with identification of individual ecosystem functions. This will allow for assessment of loss of specific environmental roles as opposed to taxon loss, which may be able to better assess ecological integrity (Dolédec & Statzner, 2010; Péru & Dolédec, 2010). Sampling protocols used in this study focused on assessments using fixed area. Future studies may want to assess this form of collection and compare it to an assessment using fixed count. Fixed count assessments may be better able to provide a stronger description of macroinvertebrate compositions than fixed area assessments (King & Richardson, 2002).

This study provided the baseline sample set for the initiation of recurring collection inside Wild Basin, a useful set of information that will assist in identifying effective ways to limit anthropogenic influences on the quality of the ecosystem. In addition, the study assessed the long-term data for significant trends. It was determined that there were no chronological shifts in water quality, suggesting that the water systems assessed are tolerant to human activity. The Austin area has had a significant rate of development in recent years. It is surprising that there is not a notable change in trend as a function of time. This suggests that current practices by environmental managers in the area have been effective in mitigating the anthropogenic inputs into the ecosystem. There is however a concern that continued development may overburden the environment and cause it to collapse.

The study also determined a significant correlation with temperature and HBI rating. This is particularly interesting since it was an unexpected observation. This trend should be further explored in order to determine the cause. The most likely scenario is that it is due to seasonal trends in population changes. The samples conducted during this study suggest that the family *Baetidae* is extremely prevalent in the area (Figure 5). It is possible the observed trend is skewed as a result. As a result, future studies may want to assess the invertebrates present in the context of their tolerances to environmental changes as a result of temperature. The trend with temperature seems to suggest the warmer it is the lower the HBI index rating. This is a curious observation as it suggests environmental health may increase with temperature. This trend should be examined in more detail and compared with chemical changes in the water as a result of changes in temperature. It is possible the chemical composition is affecting the observed populations present.

A concern derived from these changes is how climate change will affect the system. The long term assessment suggests that the system is environmentally stable. Global shifts in weather patterns may supersede local conditions and affect the balance established. The temperature trend observed may explain how the system is going to gradually change as a result of warming trends. This may have negative consequences as it will decrease local diversity. Studies in the future may want to focus on explaining the cause of the temperature trend and how climate change will most likely affect the species compositions. Overall this study is a tool to provide guidance for the future direction of assessment in the Balcones Canyonlands Preserves, particularly the Wild Basin Wilderness Preserve.

Appendix

Figure 8: Bee Creek runs through Wild Basin, northwest of Downtown Austin

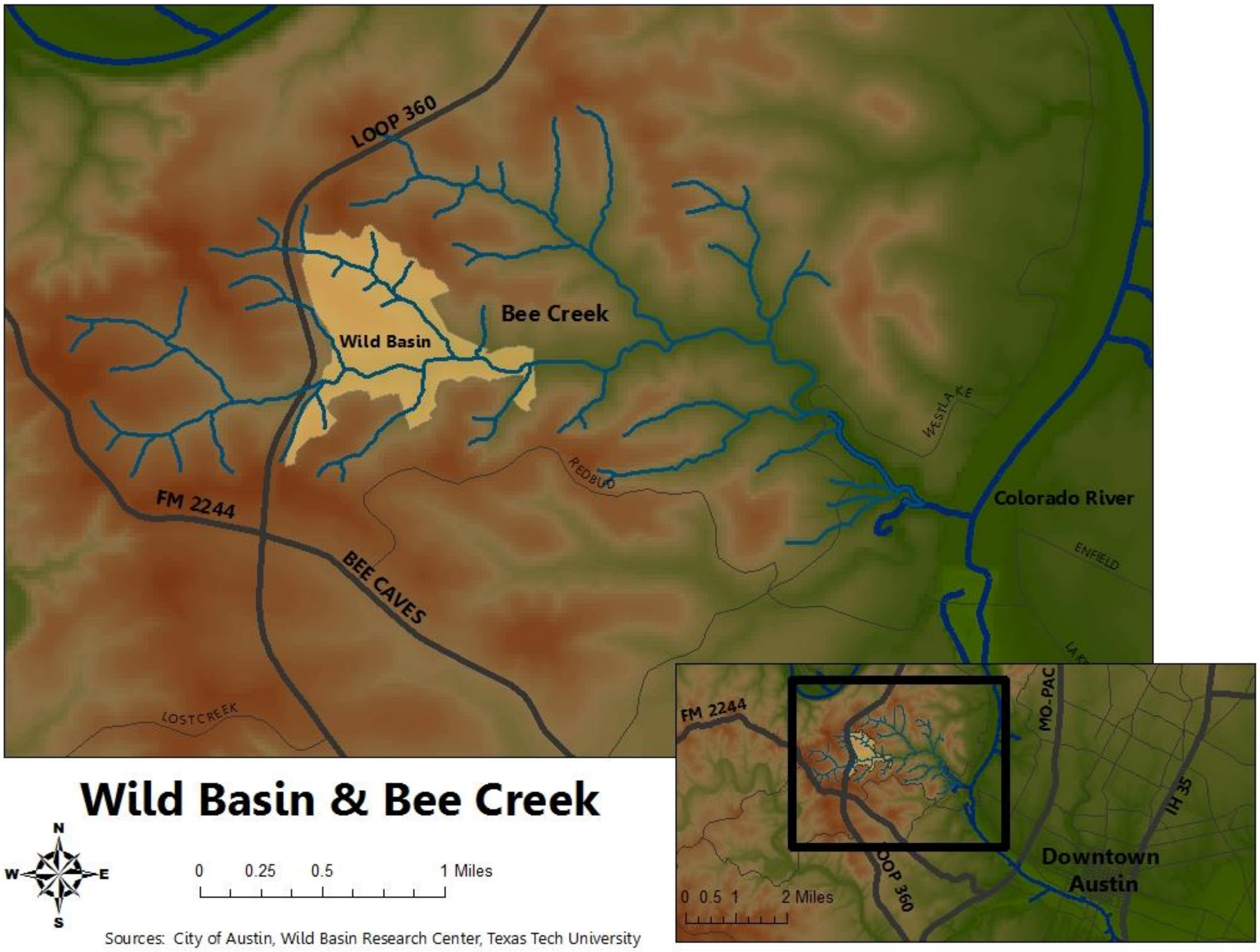

Figure 9: Subdivision property lines surround and overlap the Wild Basin Wilderness Preserve and Bee Creek

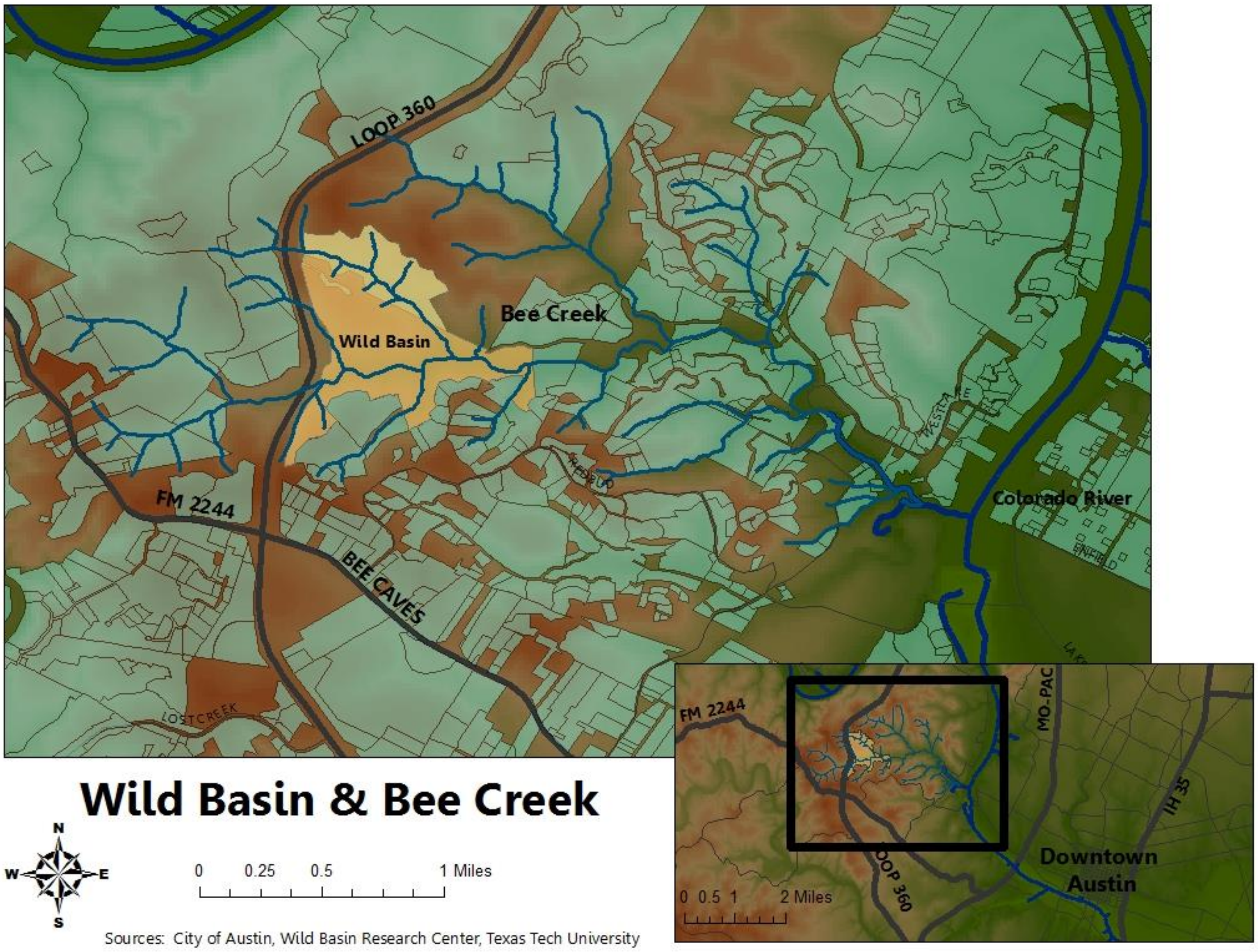

Figure 10: All sample sites of all three streams

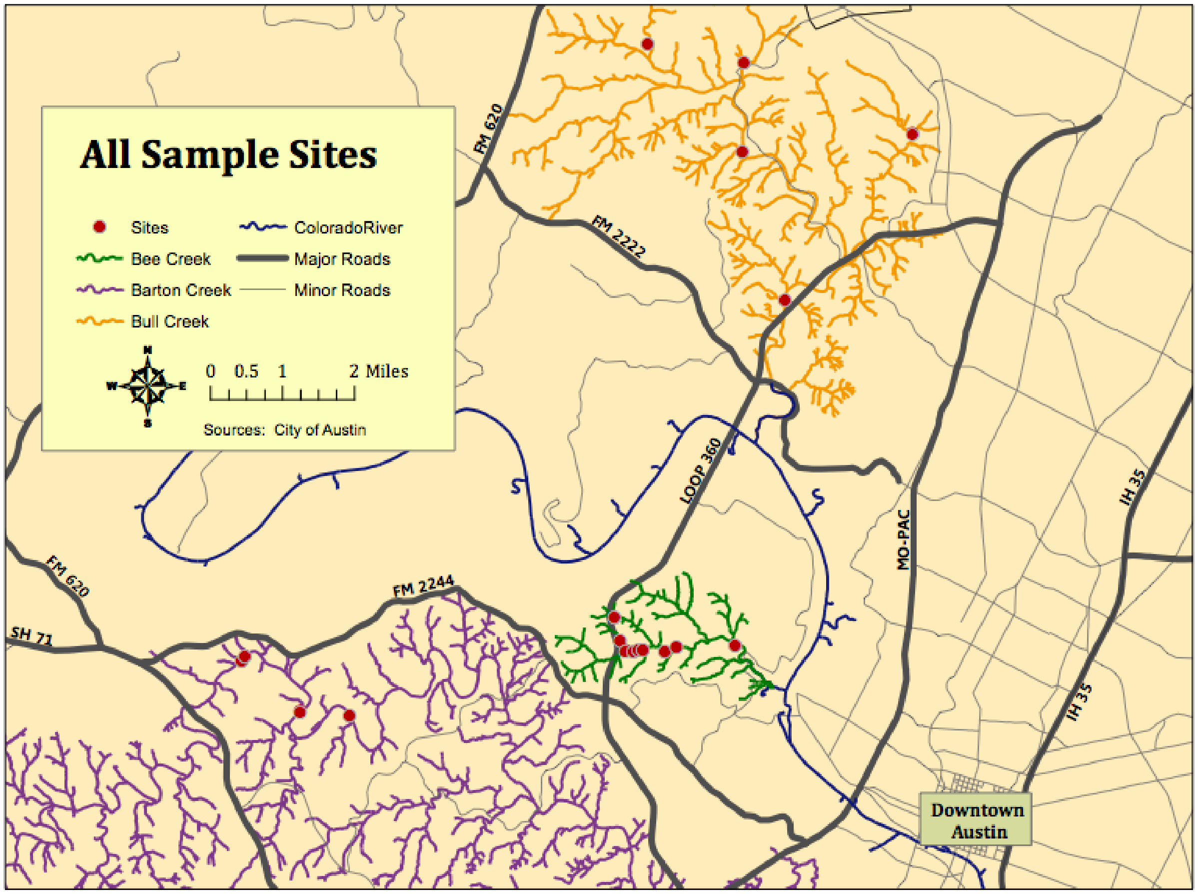
All Sample Sites
Sites
Bee Creek
Barton Creek
Bull Creek
ColoradoRiver
Major Roads
Minor Roads
0 0.5 1 2 Miles
Sources: City of Austin
FM 620
FM 2222
LOOP 360
MO-PAC
IH 35
FM 2244
SH 71
Downtown Austin

Table 1: Collection sites, their level of biodiversity and rating based on the assessment used.

Date	Associated Water2	Site	Total Diversity	Stream Health Rating
12/20/2013	Bee Creek	Resident Site 1	14	73
12/20/2013	Bee Creek	Resident Site 2	7	35
12/29/2013	Bull Creek	St. Edward's Park	20	93
12/29/2013	Bull Creek	Great Hills	8	28
1/5/2014	Bull Creek	Canyon Creek Park	15	63
1/5/2014	Bull Creek	Bull Creek Park	10	53
1/5/2014	Bull Creek	Tributary 4	17	69
1/17/2014	Bee Creek	Grotto	6	33
1/17/2014	Bee Creek	Resident Site 3	11	52
1/17/2014	Bee Creek	Trash Site	0	0
2/21/2014	Barton Creek	Nature Conservancy Site #1	19	113
2/21/2014	Barton Creek	Nature Conservancy Site #2	14	102
2/21/2014	Barton Creek	Nature Conservancy Site #3	15	98
2/21/2014	Barton Creek	Nature Conservancy Site #4	7	42
3/7/2014	Bee Creek	Resident Site 2	7	30
3/7/2014	Bee Creek	Resident Site 1	10	42
3/7/2014	Bee Creek	Resident Site 3	10	39
3/12/2014	Bull Creek	Canyon Creek Park	9	49
3/12/2014	Bull Creek	Great Hills	6	31
3/12/2014	Bull Creek	Bull Creek Park	7	36
3/12/2014	Bull Creek	Tributary 4	15	71
3/12/2014	Bull Creek	St. Edward's Park	13	62
3/13/2014	Bee Creek	Wild Basin Site #1	13	65
3/13/2014	Bee Creek	Wild Basin Site #2	9	35
3/13/2014	Bee Creek	Wild Basin Site #3	6	38
3/13/2014	Bee Creek	Wild Basin Site #4	10	50
3/14/2014	Bee Creek	Trash Site	2	10
3/14/2014	Bee Creek	Grotto	5	23

Table 2: Collections where HBI rating was used and the index rating at those sites.

Associated Water	Site	HBI Rating
Bull Creek	St. Edward's Park	4.469565217
Bull Creek	Canyon Creek Park	5.170731707
Bull Creek	Great Hills	6.272727273
Bull Creek	Bull Creek Park	4.030769231
Bull Creek	Tributary 4	4.280141844
Bee Creek	Trash Site	10
Bee Creek	Resident Site 3	6.421052632
Barton Creek	Nature Conservancy Site #1	4.740740741
Barton Creek	Nature Conservancy Site #2	4.818181818
Barton Creek	Nature Conservancy Site #3	5.333333333
Bee Creek	Wild Basin Site # 1	4.385826772
Bee Creek	Wild Basin Site #2	5.016877637
Bee Creek	Wild Basin Site #3	3.857142857
Bee Creek	Wild Basin Site #4	5.25

Table 3: Indication of taxa present at each site. 0 indicates absences and 1 indicates presence.

Date	Associated Water	Site	odanata lestidae	odanata aeshnidae	odanata coenagrionidae
2/21/14	Barton Creek	Nature Conservancy Site #1	0	0	1
2/21/14	Barton Creek	Nature Conservancy Site #2	0	1	1
2/21/14	Barton Creek	Nature Conservancy Site #3	0	0	1
2/21/14	Barton Creek	Nature Conservancy Site #4	0	0	1
12/20/13	Bee Creek	Resident Site 3	1	1	1
12/20/13	Bee Creek	Resident Site 2	0	1	0
1/17/14	Bee Creek	Grotto	0	0	0
1/17/14	Bee Creek	Trash Site	0	0	0
1/17/14	Bee Creek	Resident Site 3	0	0	0
3/7/14	Bee Creek	Resident Site 2	1	0	0
3/7/14	Bee Creek	Resident Site 1	1	1	1
3/7/14	Bee Creek	Resident Site 3	0	0	0
3/13/14	Bee Creek	Wild Basin Site #1	1	0	0
3/13/14	Bee Creek	Wild Basin Site #2	0	0	0
3/13/14	Bee Creek	Wild Basin Site #3	0	0	0
3/13/14	Bee Creek	Wild Basin Site #4	0	1	1
3/14/14	Bee Creek	Trash Site	1	0	0
3/14/14	Bee Creek	Grotto	0	0	0
12/29/13	Bull Creek	St. Edward's Park	0	1	1
1/5/13	Bull Creek	Canyon Creek Park	0	0	1
12/29/13	Bull Creek	Great Hills	1	0	0
12/29/13	Bull Creek	Bull Creek Park	0	0	0
1/5/14	Bull Creek	Tributary 4	0	1	0
3/12/14	Bull Creek	Canyon Creek Park	0	0	1
3/12/14	Bull Creek	Great Hills	1	0	1
3/12/14	Bull Creek	Bull Creek Park	0	0	0
3/12/14	Bull Creek	Tributary 4	0	0	1
3/12/14	Bull Creek	St. Edward's Park	0	0	0

odanata corduliidae	odanata gomphidae	odanata libellulidae	odanata calopterygidae	diptera tipulidae	diptera simulliidae	diptera ephydridae	dipetera culicidae	diptera stratiomyidae	diptera ceratopogonidae	diptera chironomidae	trichoptera polycentropodidae	trichoptera helicopsychidae
1	0	0	1	0	1	0	0	0	0	1	0	0
0	0	0	0	0	1	0	0	0	0	1	0	0
0	1	1	0	0	0	0	0	0	0	1	0	0
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0	0	0	0	0	1	0	0	0	1	1	0	0

trichoptera hydropsychidae	Trichoptera odontoceridae	trichoptera hydroptilidae	trichoptera philopotamidae	trichoptera rhyacophilidae	coleoptera hydrophilidae	coleoptera psephenidae	coleoptera dytiscidae	coleoptera helodidae	coleoptera elmidae	coleoptera haliplidae	coleoptera chrysomelidae	coleoptera gyrinidae	coleoptera noteridae
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0	0	0	0	0	0	0	0	0	0	0	0	0	0
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hemiptera veliidae	hemiptera naurcoridae	hemiptera pleidae	hemiptera gerridae	hemipterta notonectidae	ephermeropter caenidae	ephemeroptera baetidae	ephemeroptera siphlonuridae	ephemeropter neoephemeridae	ephemeroptera leptophlebiidae	ephemeroptera tricorythidae	emphemeroptera heptageniidae

ephemeroptera oligoneuriidae	pleocoptera perlodidae	pleocoptera perlidae	pleocoptera luctridae	Decapoda	Amphipoda	Gastropoda	annelida oligochaeta	Turbellaria	Arachnida hydracarina	Bivalvia	megaloptera corydaeidae
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